

Hemodynamics of prehypertension

Peter W de Leeuw

Dept of Medicine, Maastricht University Medical Center

Maastricht, The Netherlands

Hemodynamic characteristics of hypertension

Established hypertension

- Cardiac output normal or reduced
- Total peripheral vascular resistance increased
- Vascular compliance reduced

- Renal blood flow reduced
- Filtration fraction increased

How to study the pathogenesis of hypertension?

The ideal study would:

- Follow normotensives until they become hypertensive
- Compare offspring of hypertensives with those of normotensives
- Study the 'intermediate' phase of hypertension, i.e. between normotension and hypertension (labile hypertension, borderline hypertension, prehypertension)

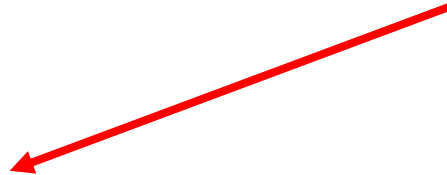
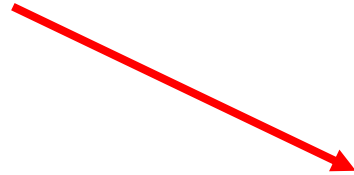
Hemodynamic basis of blood pressure

Cardiac output

Vascular resistance

Blood pressure

Arterial stiffness



Early, hemodynamic studies in borderline hypertension

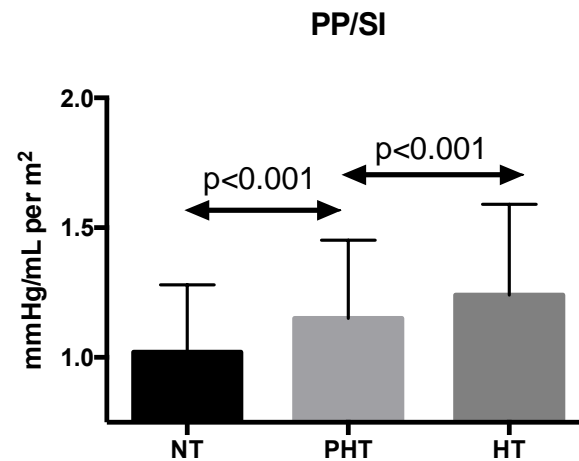
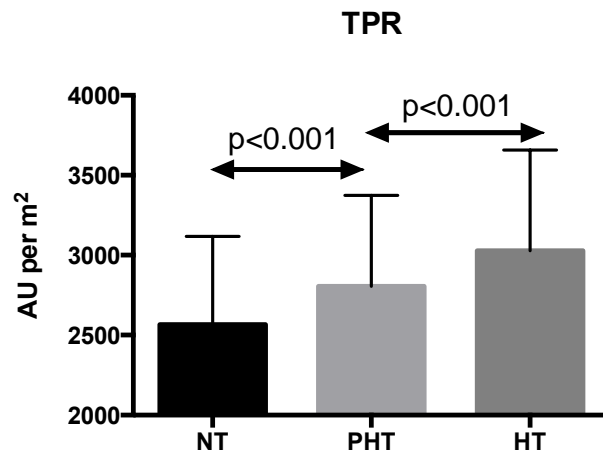
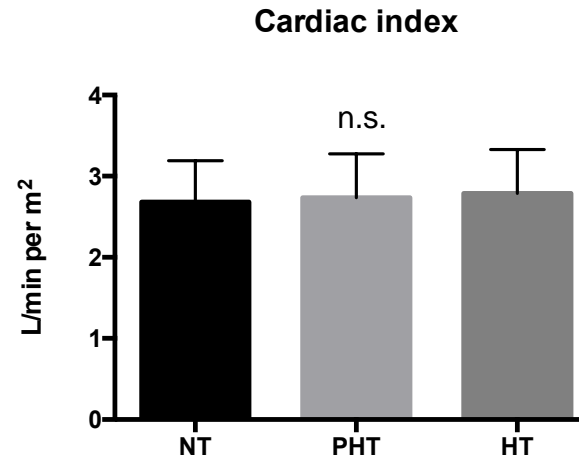
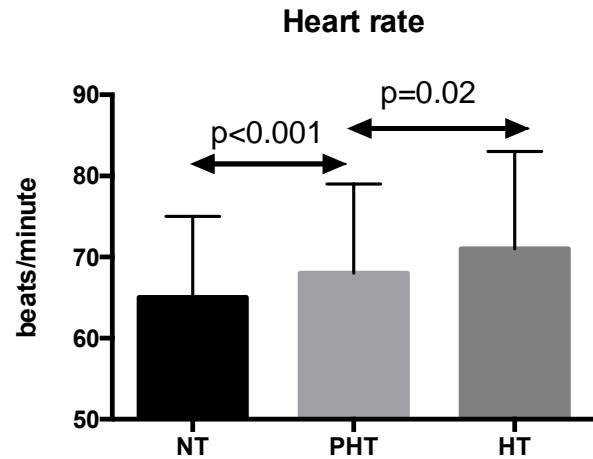
- On average, cardiac index and heart rate increased by about 15%
- Stroke volume usually normal
- Vascular resistance 'normal' although increased for the level of cardiac output
- Substantial interindividual variations

Hemodynamics in prehypertension: Strong Heart Study

- Population-based survey of cardiovascular risk factors
- American Indian communities
- Regular follow-up measurements (a.o. echocardiography)

- Fourth FU examination
 - 1940 participants < 40 years (avg. age 27 years)
 - 971 NT, 294 HT and 675 (35%) PHT

Hemodynamics in prehypertension: Strong Heart Study



Hemodynamics in prehypertension: Strong Heart Study

PHT vs NT

- Greater left ventricular mass
- More often LVH
- Presence of LVH predictor of progression from PHT to HT

Hemodynamics in prehypertension (U.S.)

Young Americans (avg. age 17 years) with PHT

- Impedance cardiography
- Whites and blacks

Hemodynamics in prehypertension (U.S.)

Phenotypes	Whites		Blacks		P (Race * BP)
	NTs	PHTs	NTs	PHTs	
TPR (U)	15.0 (0.2)	16.7 (0.7) [†]	16.2 (0.3)	16.1 (0.7)	.802
TPX (U/m ²)	25.7 (0.4)	28.8 (1.0) [†]	28.5 (0.5)	28.1 (1.1)	.042 ←
CO (L/min)*	5.4 (0.1)	5.5 (0.2)	5.2 (0.1)	5.7 (0.2) [†]	.159
CI (L/min/m ²)	3.1 (0.0)	3.2 (0.1)	3.0 (0.1)	3.3 (0.1) [†]	.117
SV (mL/beat)	85.0 (1.1)	79.8 (3.1)	81.5 (1.3)	86.9 (2.9)	.035 ←
HR (bpm)	64 (0.5)	69 (1.4) [†]	64 (0.6)	67 (1.4)	.321

Data adjusted for age, sex and BMI; [†] p<0.05 for NT vs PHT

Zhu et al. Am J Hypertens 2007;20:1051.

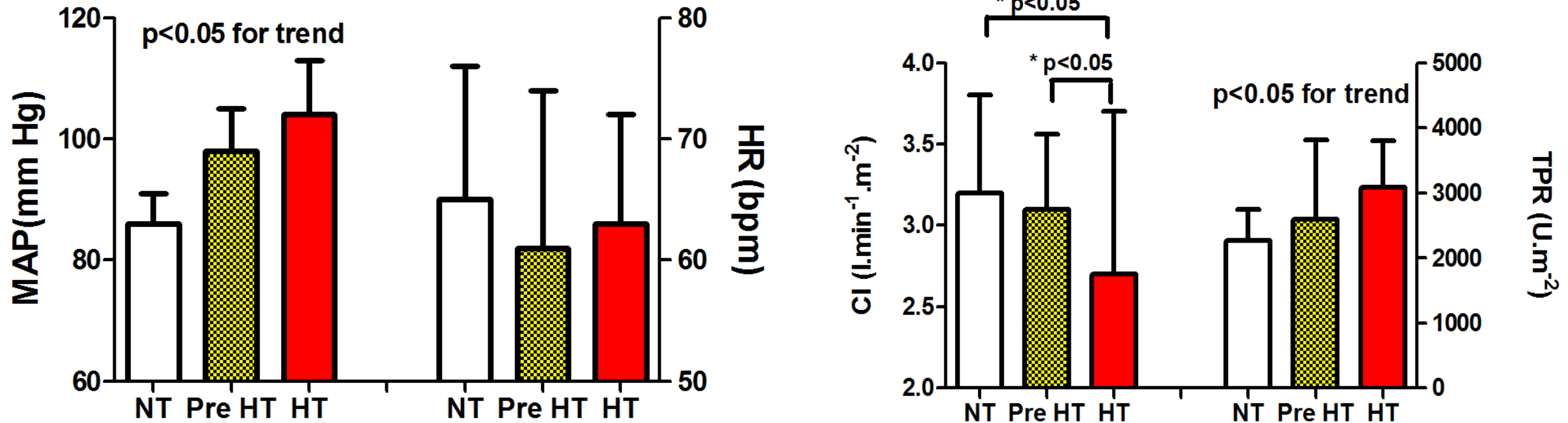
Hemodynamics in prehypertension (U.S.)

Phenotypes	Whites		Blacks		P (Race * BP)
	NTs	PHTs	NTs	PHTs	
Radial PWV (m/sec)	6.2 (0.1)	6.8 (0.1) [†]	6.7 (0.1)	6.7 (0.2)	.003 ←
Foot PWV (m/sec)	7.0 (0.1)	7.4 (0.1) [†]	7.2 (0.1)	7.2 (0.2)	.008 ←
LVMl (g/height ^{2.7})	31.1 (0.3)	31.4 (0.9)	31.4 (0.4)	32.6 (0.8)	.458

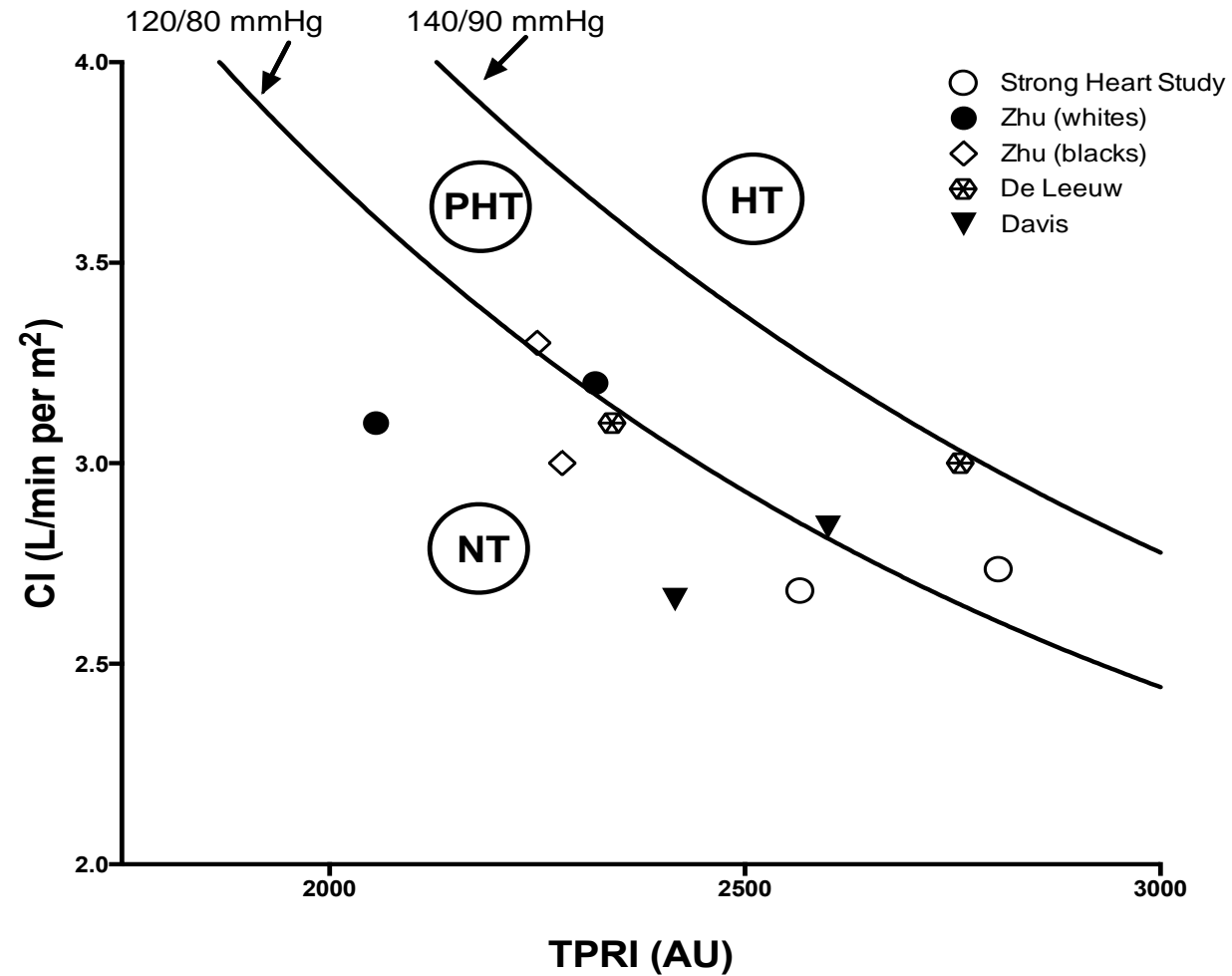
Data adjusted for age, sex and BMI; [†] p<0.05 for NT vs PHT

Zhu et al. Am J Hypertens 2007;20:1051.

Hemodynamics in prehypertension (Europe)



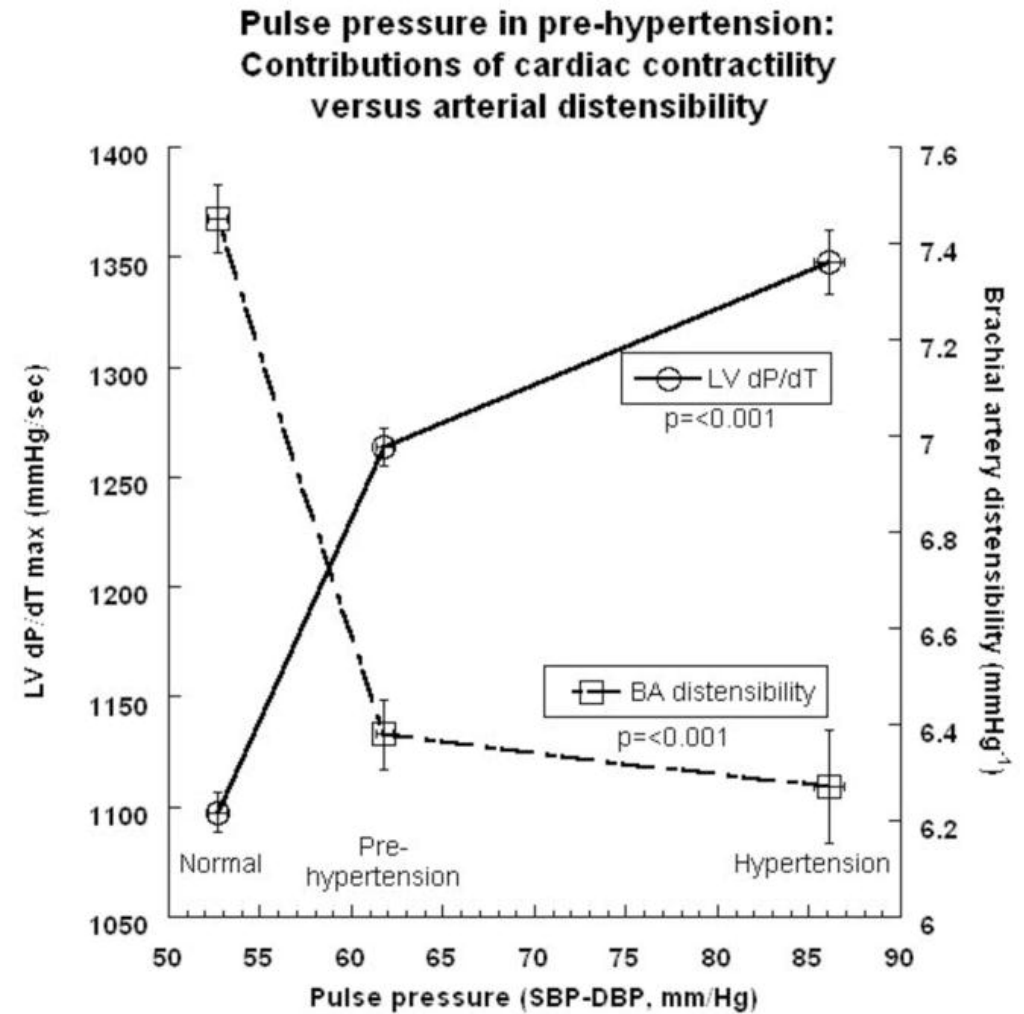
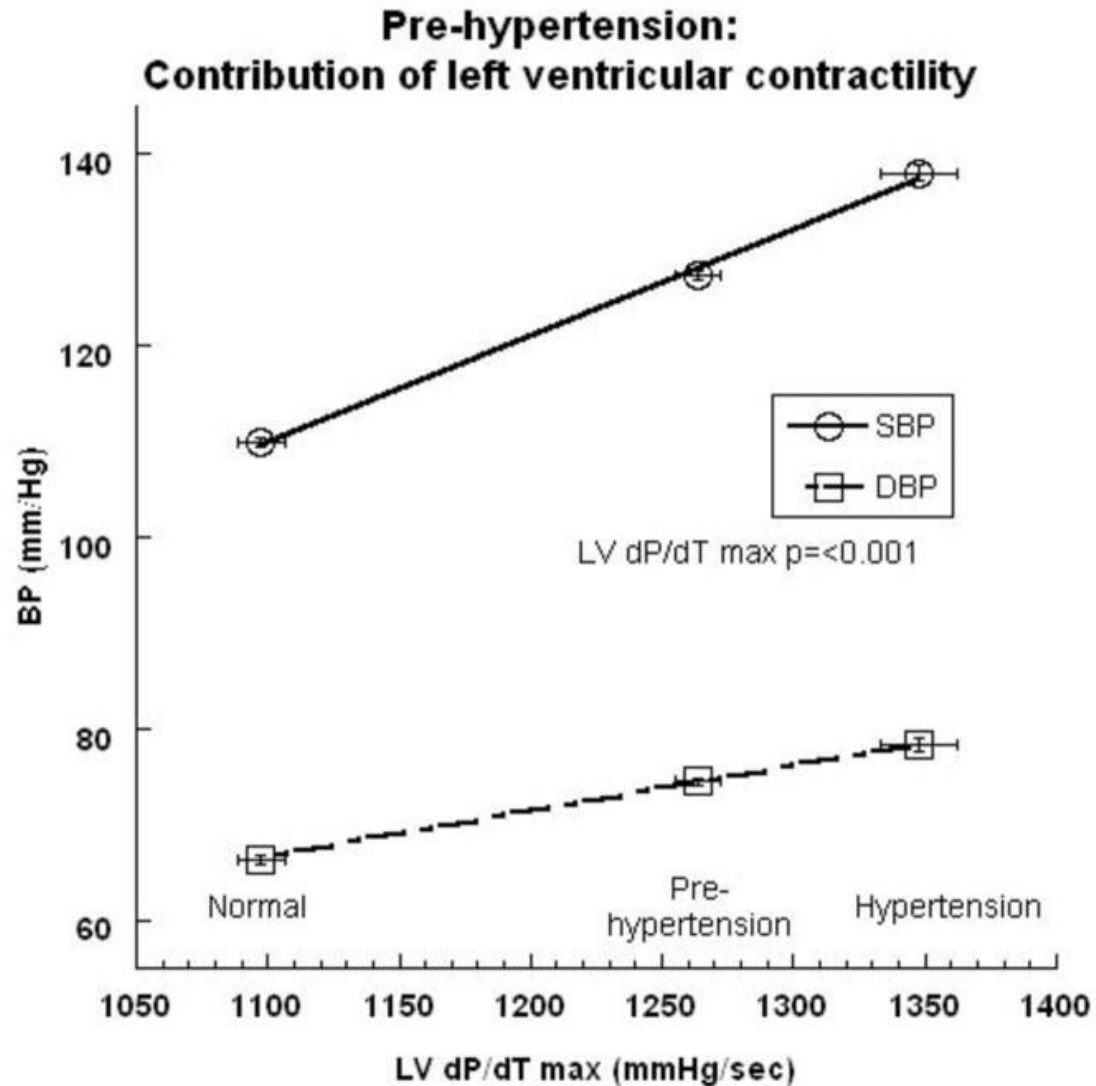
Hemodynamics in prehypertension



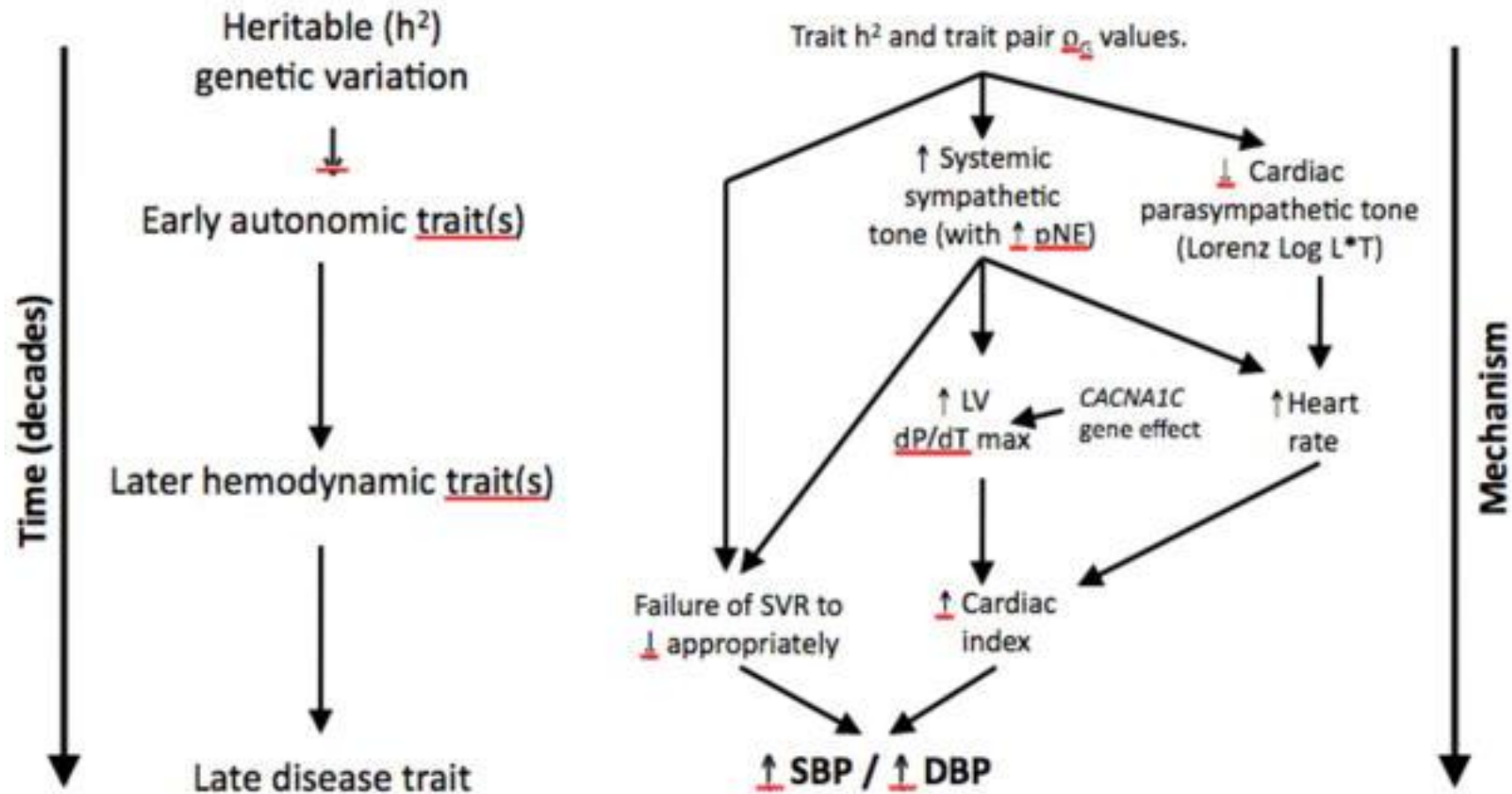
UCSD twin/family study

- Data from the University of California-San Diego twin study
- Comparison of 340 PHT and 337 NT (36 vs 38 years of age)
- Dynapulse oscillometric device (for BP and CO)
- Autonomic function tests
- Genotyping

UCSD twin/family study



Prehypertension: Hypothetical schema for heritable pleiotropic events contributing to BP elevation



Sympatho-vagal balance in prehypertension

- NT (n=118) vs PHT (n=58); age: 21 years
- CV variables measured with Finapres
- Autonomic function tests, including baroreceptor function

Sympatho-vagal balance in prehypertension

Variable	NT	PHT	p
Stroke volume (ml)	64.91 ± 8.09	72.96 ± 11.43	0.000
Left ventricular ejection time (ms)	320.75 ± 19.70	306.35 ± 20.56	0.000
Cardiac output (L/min)	4.75 ± 1.02	5.68 ± 1.27	0.000
Interbeat interval (ms)	828.78 ± 95.30	756.20 ± 82.76	0.000
TPR (mm Hg.min/L)	0.894 ± 0.22	1.125 ± 0.24	0.000
BRS (ms/mm Hg)	28.88 ± 10.20	17.15 ± 8.65	0.000

Sympatho-vagal balance in prehypertension

Variable	NT	PHT	p
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HRV parameters			
Total power of HRV (ms ²)	910.94 ± 240.03	521.06 ± 182.63	0.000
Normalized LF (LFnu)	39.59 ± 11.57	60.42 ± 10.56	0.000
Normalized HF (HFnu)	58.29 ± 12.00	37.70 ± 10.17	0.000
LF/HF ratio	0.66 ± 0.37	1.76 ± 0.75	0.000

Regional hemodynamics in borderline hypertension

- Is the increase in vascular resistance generalized or specific to certain organs?
- Determination of regional hemodynamics
- Data should be interpreted in relation to cardiac output

Regional hemodynamics in borderline hypertension

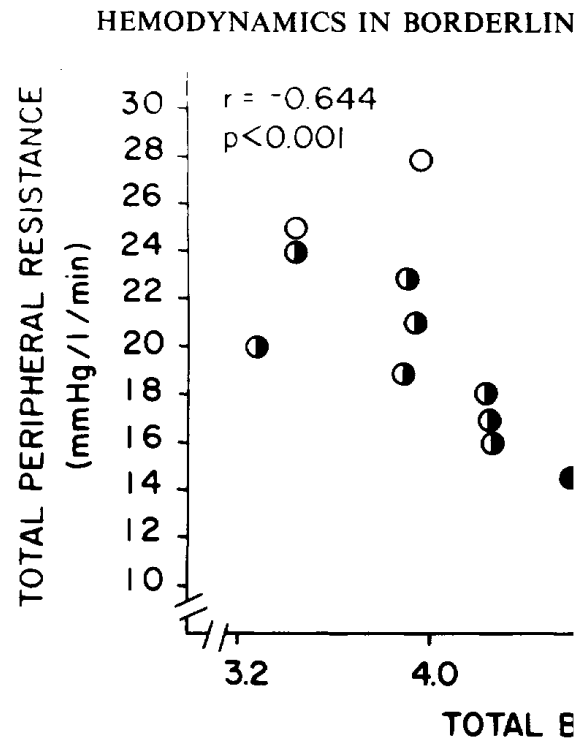
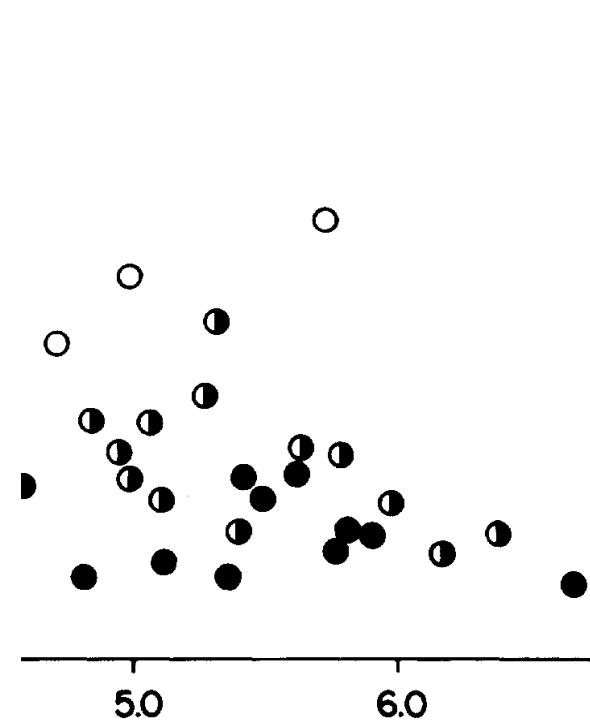


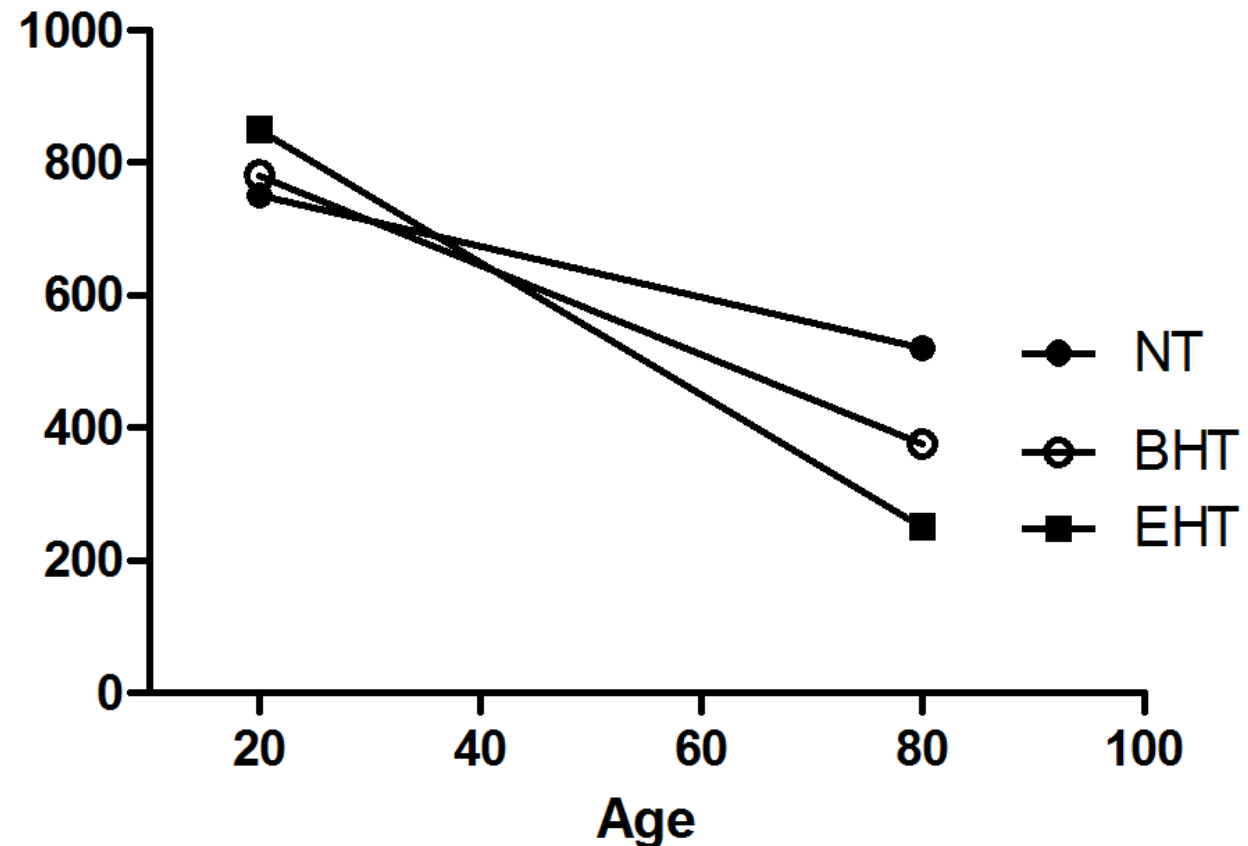
FIGURE 3. Correlation between total peripheral re
hypertensive patients with high (●), normal (○) and

IE HYPERTENSION/Messerli et al.

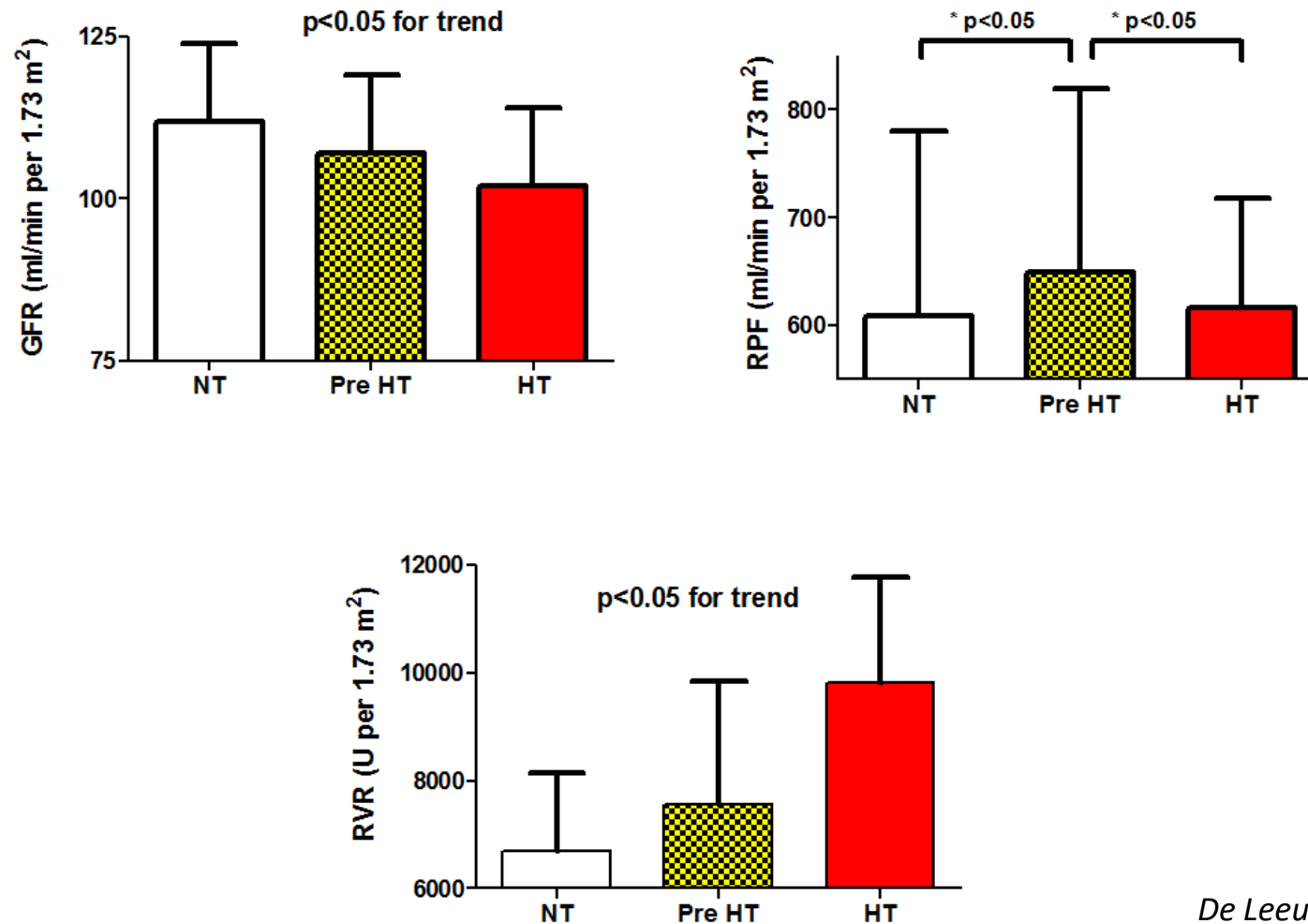
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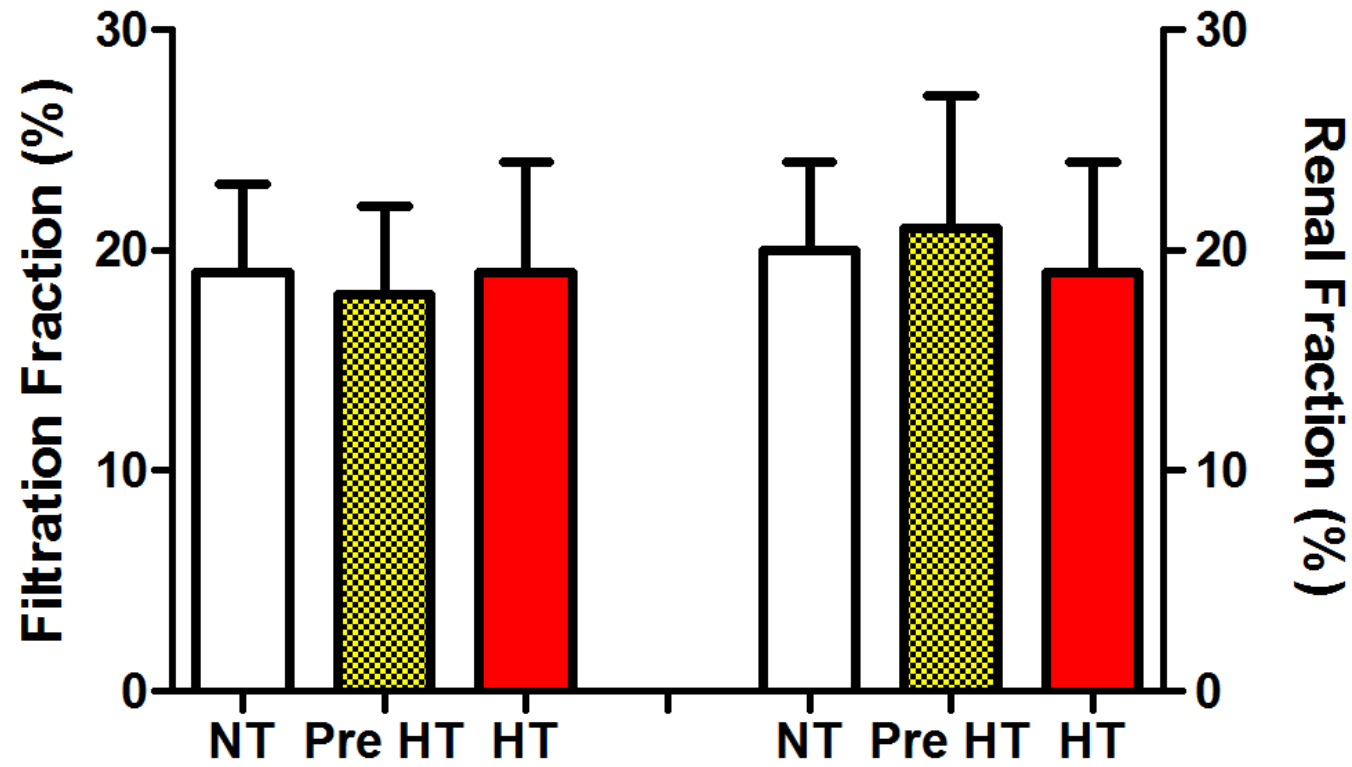
Renal hemodynamics in borderline hypertension



Renal hemodynamics in prehypertension



Renal hemodynamics in prehypertension



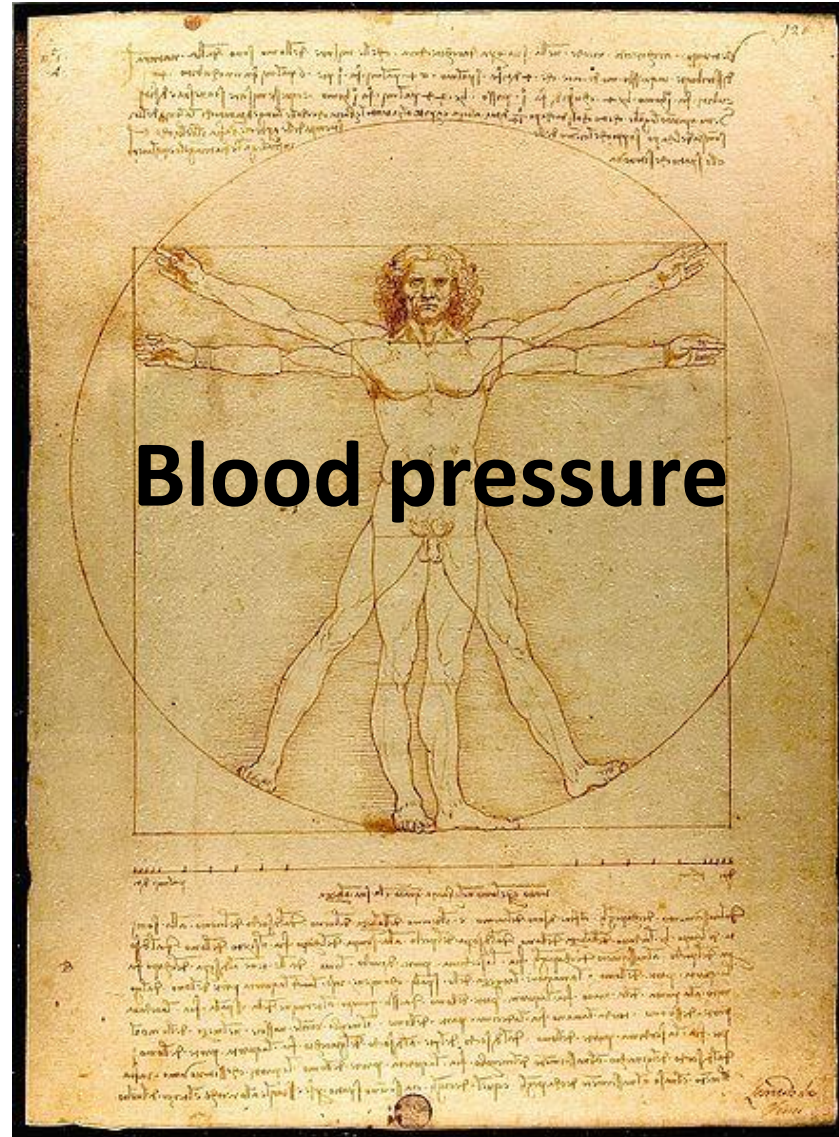
Regional hemodynamics in prehypertension

- Erdogan et al. Circulation 2007;115:593.
 - 50 NT, 40 PHT
 - HR similar, LV mass similar
 - Coronary flow reserve lower in PHT (coronary resistance increased)

- Grassi et al. Curr Pharm Des 2013;19:2375.
 - Review of previous studies
 - In PHT more abnormalities of the retinal circulation (A-V ratio reduced)

Hemodynamic basis of prehypertension

Cardiac output



Blood pressure

Vascular resistance

Arterial stiffness

Conclusions

- Hemodynamic data in PHT are remarkably similar to those obtained previously in borderline HT and suggest that PHT is a transitional state
- Although CO may be increased in a subset of 'patients' with PHT, the most consistent finding is a rise in vascular resistance and in arterial stiffness
- The increased vascular resistance is, at least initially, generalized and not regional
- Enhanced sympathetic drive and reduced baroreceptor sensitivity may underlie the hemodynamic abnormalities of PHT